Finescale Water-Mass Variability from ARGO Profiling Floats

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LONGTERM GOALS

My longterm goals are to understanding the processes responsible for stirring and mixing in the ocean so that their impacts on larger scales may be accuratey parameterized.

OBJECTIVES

To obtain a global assessment of water-mass (aka thermohaline or spice) variability as a measure of stirring along isopycnals, as well as density ratio R_ρ statistics, from the global ARGO profiling float data set.

APPROACH

For the water-mass analysis, the profile data is transformed onto σ_θ density coordinates where salinity anomalies S' are used as a proxy for water-mass variability. Salinity anomalies S' are compared with 300-km scale salinity-gradients on isopycnals to determine eddy stirring lengths. These are combined with velocity fluctuations from the ECCO2 global state estimate (Menemenlis *et al.* 2005) to estimate 300-km scale horizontal diffusivities to 2000-m depth. These are being compared to the Ferrari and Nikurshin (2010) eddy suppression theory to determine if eddy stirring is damped in jets. In the vertical, density ratio R_ρ statistics have been mapped. If time permits we will search the data for outliers in T,S and stratification N^2 to map vortices analogous to Meddies though this may not be warranted as described below.

WORK COMPLETED

The global ARGO profiling float data set through 2012 has been downloaded from its archive and catalogued. Postdoctoral researcher Dr. Cimarron Wortham arrived in September 2013 after completing a PhD under Carl Wunsch's supervision at MIT to take the lead on the eddy-stirring analysis. An early concern was the estimate of eddy stirring length might be biased high by near-zero background gradients but this proved to be a non-issue for all but 4% of the data. Upon learning in 2014 that Dr. Sylvia Cole (WHOI) was carrying out similar analysis, we collaborated to avoid duplication of effort. This afforded the opportunity to compare the two approaches which revealed some opportunity for improvement for both groups. A first paper has been published with Dr. Cole as

lead author. Dr. Wortham is taking the lead on the second MS on eddy suppression while the PI is taking the lead on density ratio results.

RESULTS

We have confirmed that no horizontal coherence of water-mass anomalies as a function of vertical wavenumber is universal, as reported by Ferrari and Polzin (2005) for the eastern North Atlantic. This argues for strong stirring. Eddy stirring creates more water-mass variability than vertical mixing (Cole *et al.* 2015). Most eddy lengthscales λ are less than 600 km (Fig. 1), suggesting that local eddy stirring is more important than long-range propagation of isolated vorticies such as Meddies. The eddy diffusivity κ_h is found to vary over 2 orders of magnitude with latitude, longitude and depth (Figs. 1 and 2). It is elevated in zonal bands associaed with strong currents including western boundary current extension, the Antarctic Circumpolar Current and equatorial jets. A subsurface maximum is found in 27% of the ocean (Fig. 2), consistent with the predictions of Ferrari and Nikurashin (2010). However, their prediction of eddy suppression in mean jets doesn't hold within 20º of the equator where our diffusivities are significantly higher.

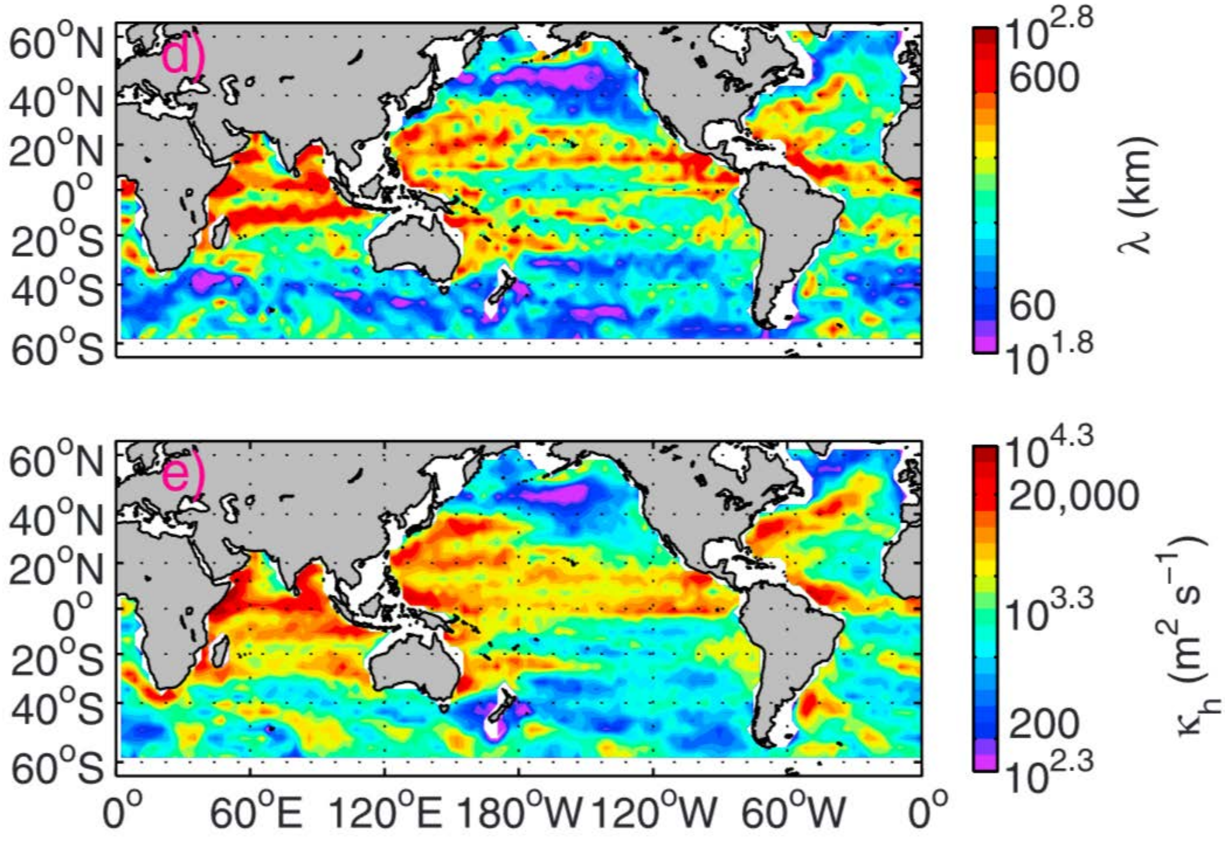

Figure 1: Global maps of eddy stirring length λ (upper panel) and 300-km horizontal diffusivity κ_h (lower panel) at the base of the winter mixed-layer in the upper pycnocline (from Cole et al. 2013).

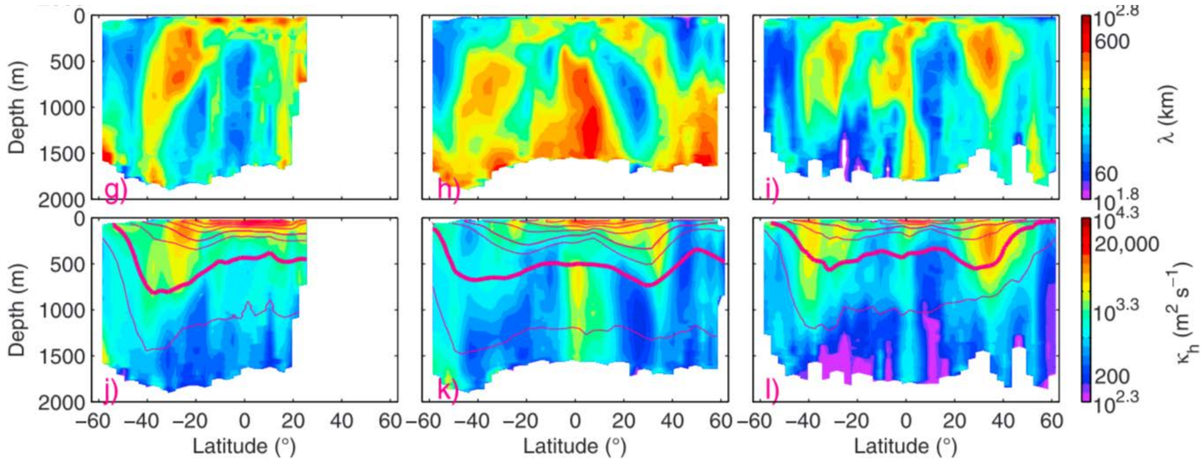

Figure 2: Latitude-depth sections of average eddy stirring length λ (upper panels) and 300-km horizontal diffusivities κ_h (lower panels) in the Indian (left), Pacific (center) and Atlantic (right).

Density ratio R_ρ statistics find that strongly salt-fingering-favorable conditions ($R_\rho < 2$) occupy a significant fraction of the water column almost everywhere. These might arise from vertical shearing of water-mass anomalies by the eddy field (Schmitt 1990) or double-diffusively-driven thermohaline interleaving. The coarse temporal and vertical sampling of the data are unlikely to allow us to distinguish between these 2 mechanisms though persistent thermohaline intrusions spanning O(1000 km) have been reported in the equatorial Pacific (Richards 1991).

IMPACT/APPLICATIONS

Global mapping of water properties has focussed on smoothed basin-scale fields in the past (e.g., You 2002). The dramatic increase in data afforded by the ARGO profiling float array allows mesoscale variances and lengthscales to be examined as well. Work to date has extended previous surface estimates of eddy diffusivities to depths of 2000 m, allowing better statistics for testing of OGCMs. Mesoscale water-mass variability on isopycnals provides signatures of stirring on the outer scales of geostrophic turbulence. This stirring initiates a cascade to the submesoscale and finescale that allows more of the ocean to be double-diffusively unstable than previously reported.

RELATED PROJECTS

This project determined the global distribution of finescale water-mass variability arising from stirring by the mesoscale eddy field to parameterize lateral stirring and mixing on O(100 km) lengthscales so complements submesoscale results from ONR's Lateral Mixing DRI where I synthesized a horizontal wavenumber spectrum for water-mass variability for horizontal wavelengths of 0.03-10 km based on data collected from 5 towyo and autonomous platforms in the Sargasso Sea (Kunze *et al.* 2015) and examined the role of intermittency in turbulent mixing on horizontal internal-wave strain dispersion (Kunze and Sundermeyer 2015).

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PUBLICATIONS

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